New Features of HEC-RAS 3.1 and HEC-GeoRAS 3.1

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Abstract

Version 3.1 of HEC-RAS and HEC-GeoRAS were released in December of 2002. This paper will discuss the major new features that were added to these software products since their previous releases. For HEC-RAS, most of these new features centered around additional options for unsteady flow routing, such as: dam and levee breaching; mixed flow regime for unsteady flow; pump stations; navigation dam operations; culvert flap gates; floodway encroachments; and stable channel design and analysis. Some of the main new features in HEC-GeoRAS are: levee alignments; storage areas; and ineffective flow areas. These features as well as others will be discussed in this paper.

INTRODUCTION

Many new features have been added to the HEC-RAS and HEC-GeoRAS software products for the Version 3.1 release. This paper will discuss the major new features that have been added to each of these programs.

NEW FEATURES FOR HEC-RAS 3.1

Most of the new features found in HEC-RAS center around performing an unsteady flow analysis. The ability to perform one-dimensional unsteady flow analysis was added to HEC-RAS and first released in March of 2001 (Version 3.0). Several new features have been added to the software since the first unsteady flow release, including: mixed flow regime analysis for unsteady flow, dam break capability, levee breaching, pump stations, culvert flap gates, navigation dam operations, floodway encroachments, and stable channel design and analysis.

Mixed Flow Regime

Modeling mixed flow regime (subcritical, supercritical, hydraulic jumps, and draw downs) is quite complicated with an unsteady flow model. In general, most unsteady flow solution algorithms become unstable when the flow passes through critical depth. The solution of the unsteady flow equations is accomplished by calculating derivatives (changes in depth and velocity with respect to time and space) in order to solve the equations. When the flow passes through critical depth, the derivatives become very large and begin to cause oscillations in the solution. These oscillations tend to grow larger until the program goes completely unstable.

In order to solve the stability problem for a mixed flow regime system, Dr. Danny Fread (Fread, 1986) developed a methodology called the "Local Partial Inertia Technique." This methodology applies a reduction factor to the two inertia terms in the momentum equation as the Froude number goes towards 1.0. The modified momentum equation is show below:

$$\sigma\left[\frac{\partial Q}{\partial t}+\frac{\partial\left(\frac{\beta Q^2}{A}\right)}{\partial x}\right]+gA\left(\frac{\partial h}{\partial x}+S_f\right)=0$$

and

$$\begin{aligned}\sigma &= F_T - F_r^m \quad (F_r \le F_T\ ;\ m \ge 1)\\ \sigma &= 0 \quad\quad\quad\quad (F_r > F_T)\end{aligned}$$

where:	σ	=	LPI factor to multiply by inertial terms.
	FT	=	Froude number threshold at which factor is set to zero. This value should range from 1.0 to 2.0 (default is 1.0)
	Fr	=	Froude number.
	m	=	Exponent of equation, which changes shape of the curve. This exponent can range between 1 and 128 (default value is 10).
	h	=	Water surface elevation
	S_f	=	Friction slope
	Q	=	Flow rate (discharge)
	A	=	Active cross sectional area
	g	=	Gravitational force

The default values for the equation are $F_T = 1.0$ and m = 10. When the Froude number is greater than the threshold value, the factor is set to zero. The user can change both the Froude number threshold and the exponent. As you increase the value of both the threshold and the exponent, you decrease stability but increase accuracy. As you decrease the value of the threshold and/or the exponent, you increase stability but decrease accuracy. To change either the threshold or the exponent, select **Mixed Flow Options** from the **Options** menu of the Unsteady Flow Analysis window. When this option is selected, the mixed flow regime options window will appear as shown in Figure 1.

As shown in Figure 1, the graphic displays what the magnitude of the LPI factor will be for a give Froude number and a given exponent m. Each curve on the graph represents an equation with a threshold of 1.0 (F_T) and a different exponent (m).

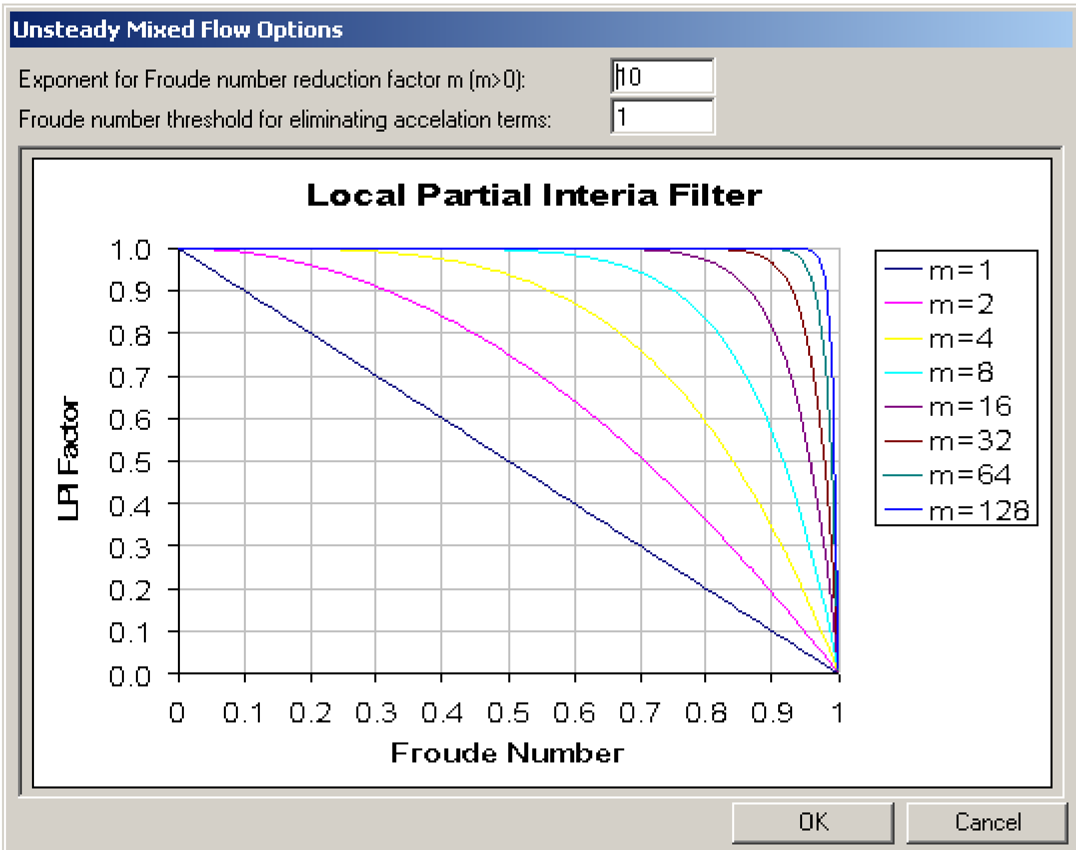


Figure 1. Mixed Flow Options Window

By default, the mixed flow regime option is not turned on. To turn this option on you simple check the **Mixed Flow Regime** box, which is contained within the computational settings area of the Unsteady Flow Analysis window.

Modeling Dam Breaks

HEC-RAS can be used to model both overtopping as well as piping failure breaches for earthen dams. Additionally, the more instantaneous type of failures of concrete dams (generally occurring from earthquakes) can also be modeled. The resulting flood wave is routed downstream using the unsteady flow equations. Inundation mapping of the resulting flood can be done with the HEC-GeoRAS program (companion product to HEC-RAS) when GIS data (terrain data) are available.

Dams are modeled within HEC-RAS by using the Inline Structure editor. The Inline Structure editor allows the user to put in an embankment, define overflow spillways and weirs, and gated openings (radial and sluice gates). Gated openings can be controlled with a time series of gate openings or using the elevation control gate operation feature in HEC-RAS.

Dam breaching information is entered from a separate window that can be brought up from either the Inline Structure editor, or from as an Option from the Unsteady Flow Computations window. The Dam Breach editor is shown in Figure 2.

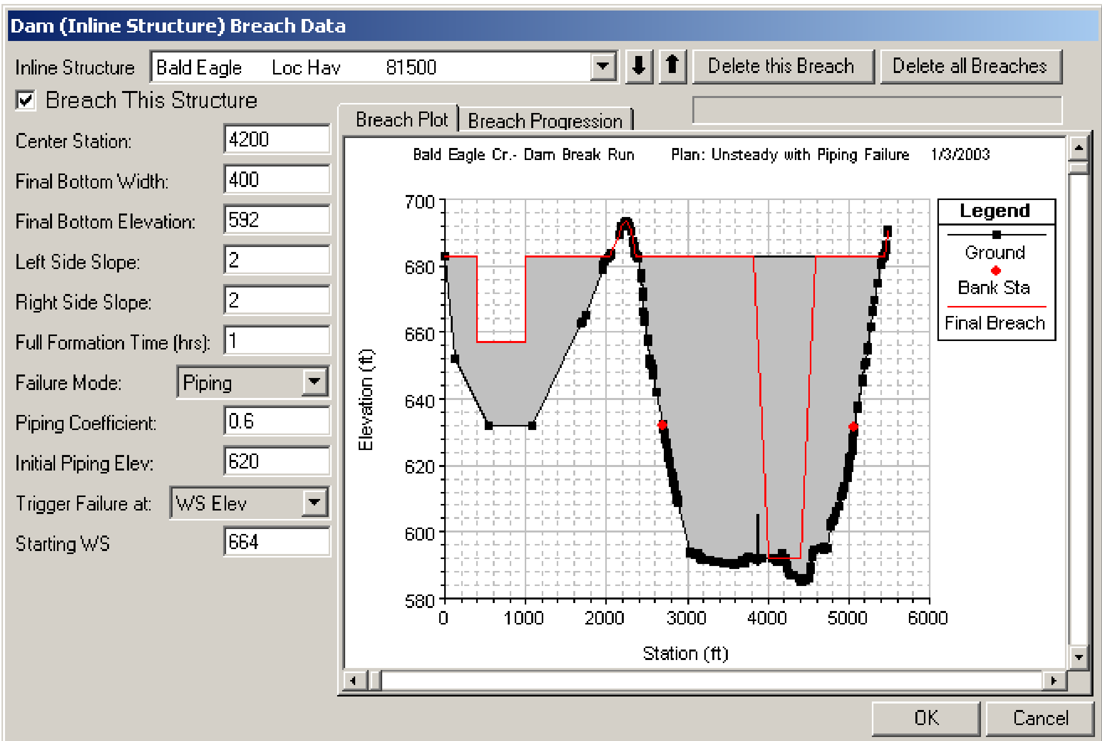


Figure 2. Dam Breach Data Editor

As shown in Figure 2, the user enters the following data to describe the breach: the center stationing of the breach; the final bottom width; final bottom elevation; left side slope; right side slope; full breach formation time; failure mode (overtopping or piping failure); piping coefficient for orifice type flow; initial elevation of the piping failure; failure trigger mechanism (water surface elevation or time); and water surface or time at which failure begins.

The breach progression can either be linear (default) or user-specified. If the Breach Progression tab is selected a table will appear in the graphic display window. The table is used to enter a breach progression curve for the formation of the breach. This is an optional feature. If no curve is entered, the program automatically uses a linear breach progression rate. This means that the dimensions of the breach will grow in a linear manner during the time entered as the full breach formation time. Optionally, the user can enter a curve to represent the breach formation as it will occur during the breach development time. The curve is entered as Time Fraction vs. Breach Fraction. The Time Fraction is the decimal percentage of the full breach formation time. The breach fraction is the decimal percentage of the breach size. Both factors are entered as numbers between zero and one. An example of a user entered nonlinear breach progression rate is shown in Figure 3.

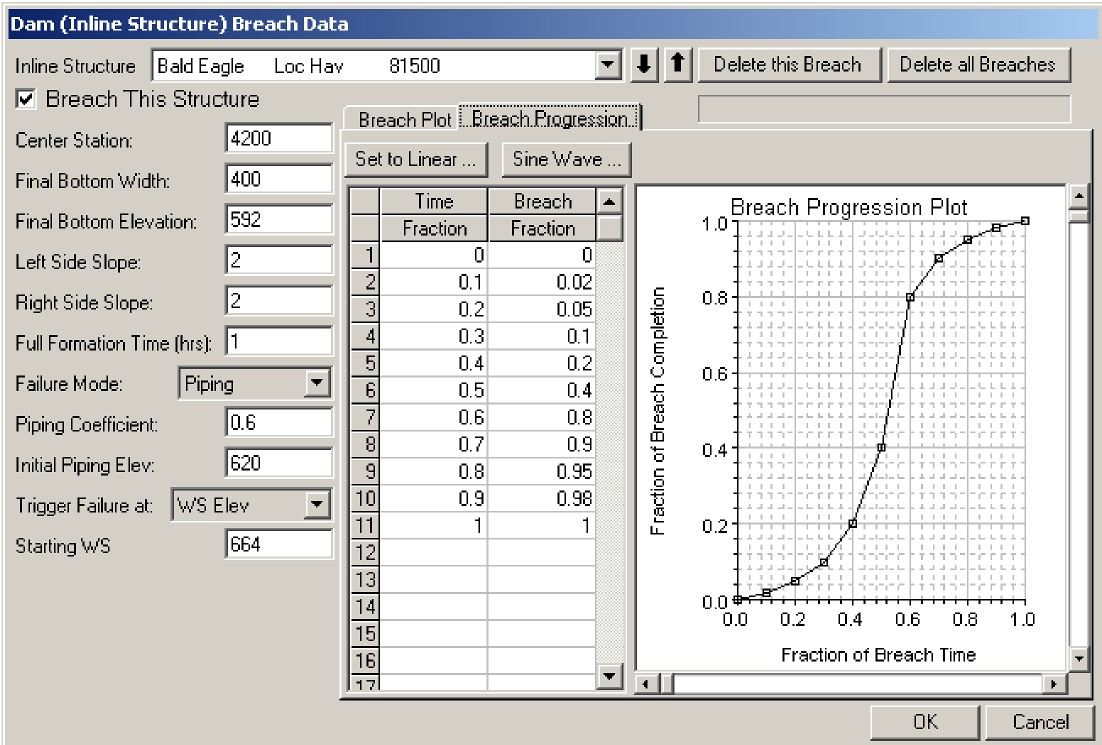


Figure 3. Non-Linear Breach Progression Tab

For the HEC-RAS software, the user must estimate the maximum breach dimensions and breach formation time outside of the program. Because the breaching process is complex, it is suggested that the modeler try to come up with several estimates of the breach parameters, and then put together a matrix of potential breach sizes and times. One example would be to use two different sets of regression equations and one of the breach simulation models to estimate the breach parameters. In several studies performed at HEC we have used both the Froelich (1995) and the MacDonald\Langridge-Monopolis (1984) regression equations, as well as the BREACH model by Dr. Danny Fread (Fread, 1988). All three methods give different answers for the breach dimensions, as well as the time for the breach to form. One could simply run each of these estimates as a separate trial within HEC-RAS, or a matrix could be formed by trying all three breach times with each of the breach sizes, thus ending up with nine different runs. Either way, it is always good to test the sensitivity of the breaching parameters, since they are the most unknown factor in this process.

Once a dam breach analysis is run within HEC-RAS, several plots and tables are available for evaluating the results. Graphics include cross section, profile, and 3-dimensional plots, all of which can be animated on a time step by time step basis to visualize the propagation of the flood wave. An example cross-section plot of a dam breach in progression is shown in Figure 4. Shown in Figure 5 is the resulting flow hydrographs for several locations below the dam.

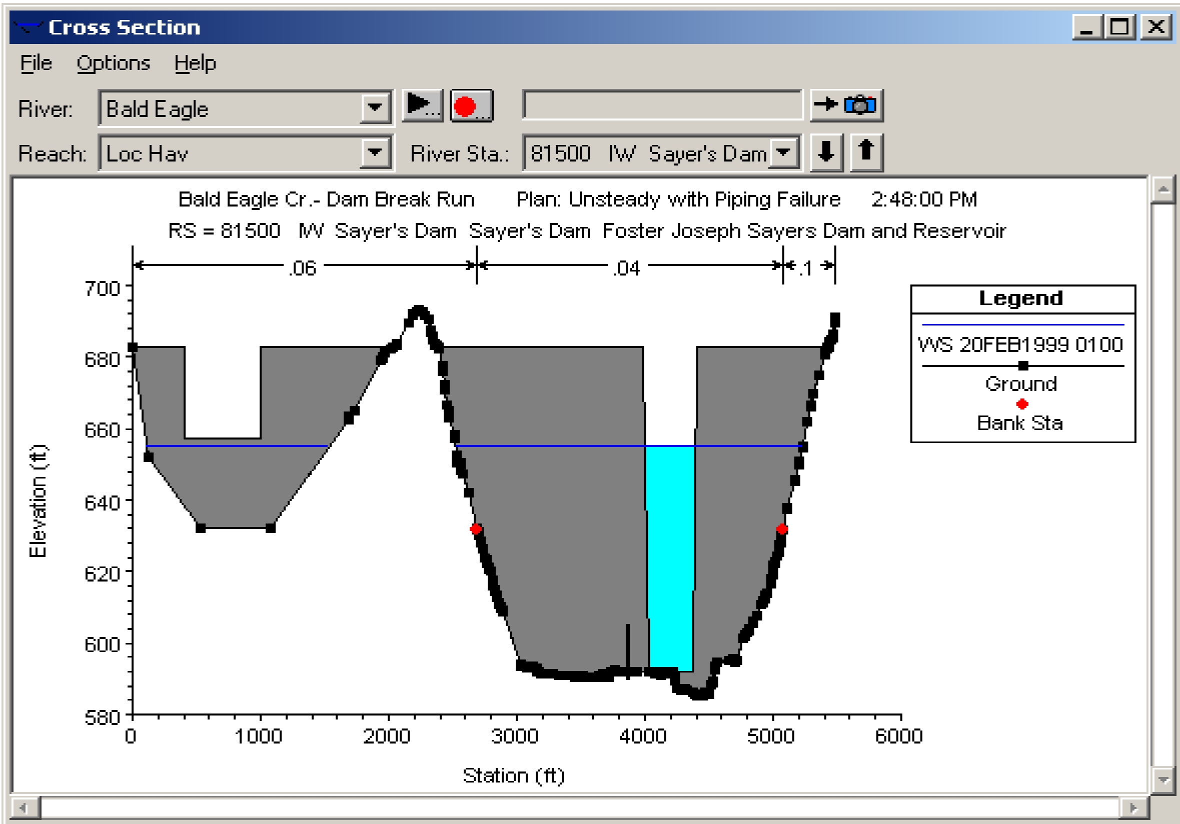


Figure 4. Example Plot of Dam While Breaching

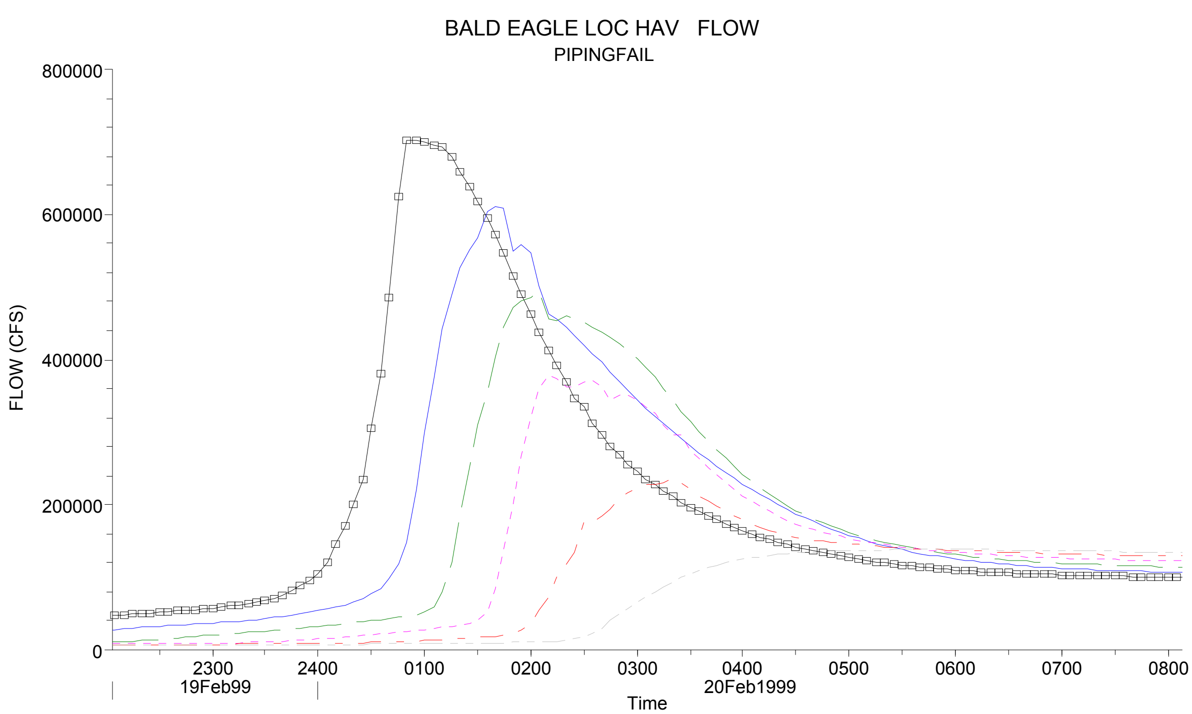


Figure 5. Flow Hydrographs From Dam to Downstream Locations

Levee Overtopping and Breaching

Levee overtopping and breaching can be analyzed within HEC-RAS by modeling the levee as a lateral structure. When modeling a levee with a lateral structure, the area behind the levee should not be included in the cross section data of the main river. The cross sections should stop right at the bottom of the levee. The lateral structure (levee) can be connected to a storage area or another river reach. How you model the area behind the levee will depend upon what will happen to the water if the levee overtops or breaches. If the water going over or through the levee will pond, then a storage area would be appropriate for modeling the area behind the levee. If the water will continue to flow in the downstream direction, and possibly join back into the main river, then it may be more appropriate to model that area as a separate river reach. Shown in Figure 6 is an example schematic with a levee modeled as a lateral structure connected to a storage area to represent the area behind the levee.

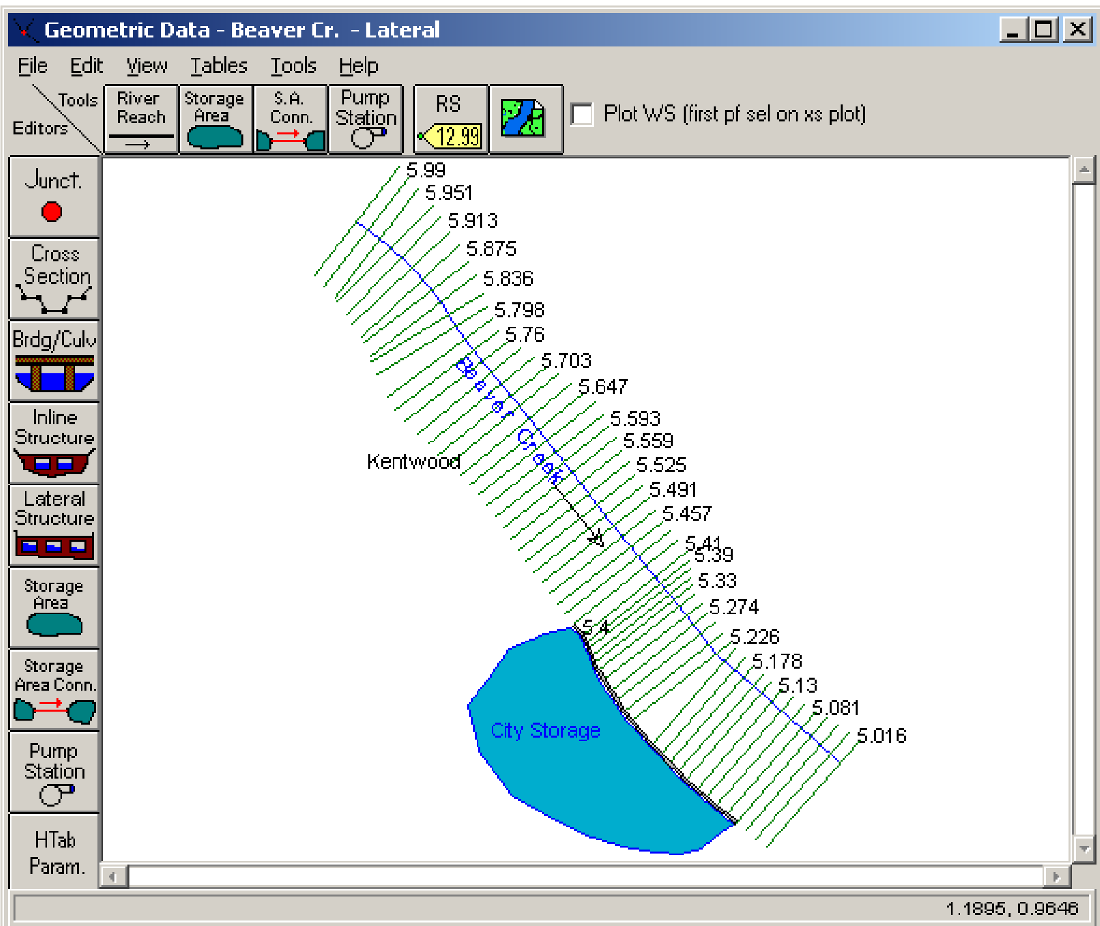


Figure 6. HEC-RAS Schematic with Example Levee and Storage Area

The information used to describe the levee is entered as a weir/embankment within the Lateral Structure editor. By modeling the levee this way, if the water surface overtops the levee without breaching it, then the software will model the flow going over the levee as weir flow. The data used to describe the breach is exactly the same as a dam break, which was described previously in this paper. The breach can be either an overtopping failure or a piping failure.

After all of the data are entered and the computations are performed, the user can begin to look at output for the lateral structure (levee). Plots such as the profile plot, lateral structure hydrographs, and storage area hydrographs, can be very helpful in understanding the output for a levee overtopping and/or breach. Shown in Figure 7 is an example profile plot with a levee breach.

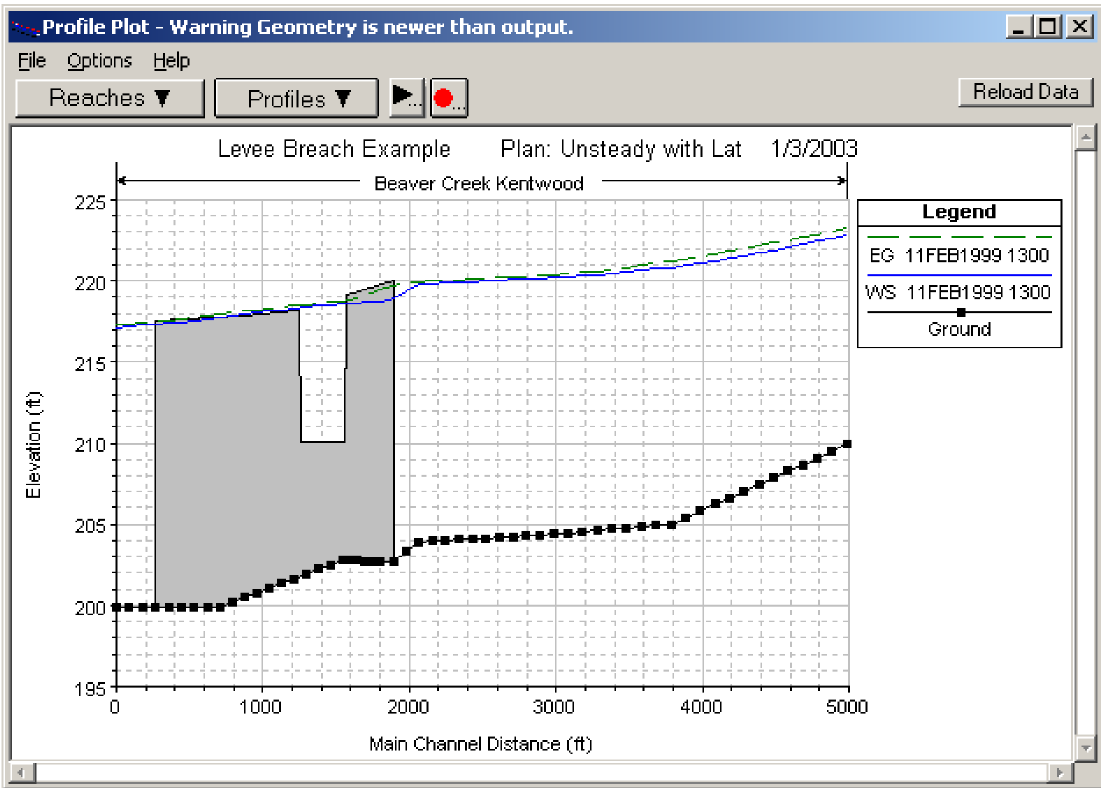


Figure 7. Profile Plot With Levee Breach

Modeling Pump Stations

Pump stations can be connected between storage areas; a storage area and a river; and between river reaches. The user can have up to 10 different pump groups, and each pump group can have up to 20 identical pumps. Each pump group can have its own head versus flow curve, and each pump within a group can have its own on and off trigger elevation. Pump stations can be used for many purposes, such as pumping water stored behind a levee (interior sump) into the main river. An example schematic of an interior ponding area behind a levee is shown in Figure 8. Note that the pump is connected from the storage area to a river station at the downstream end of the levee.

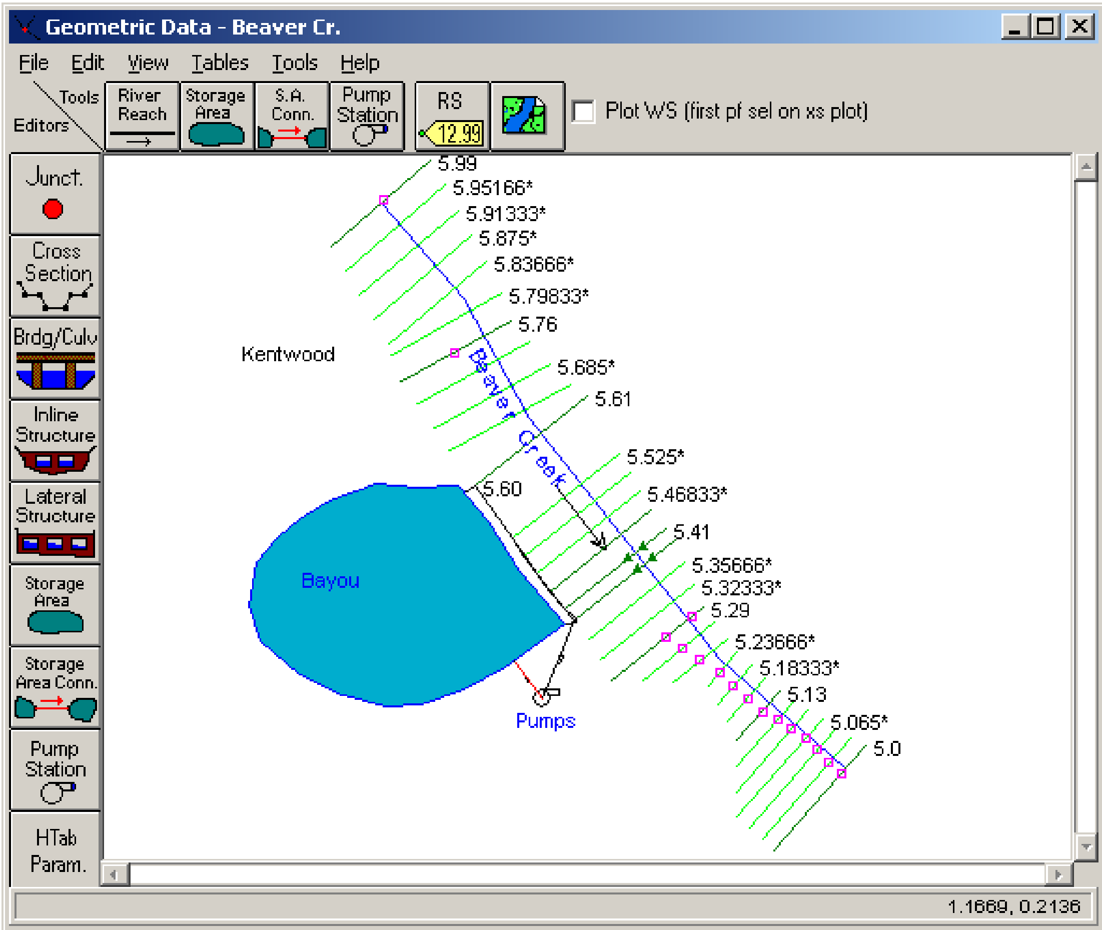


Figure 8. Pump Station Connected From a Storage Area to The River

Culvert Flap Gates

Flap gates can be added to any culvert that is defined as part of a lateral structure. The flap gate can be used to limit flow to one direction through the culvert. For example, interior ponding areas behind levees will often have a culvert connecting the interior area to the main river. A flap gate is placed on the river side of the levee, such that when the river is higher than the interior area, no flow can go back into the interior area through the culvert. However, after the river recedes, water can flow from the interior area to the river.

Navigation Dam Operations

HEC-RAS has the ability to model a navigation dam. Navigation dams are used to maintain upstream water levels within a range of elevations in order to allow for ship travel upstream. The HEC-RAS software can be used to predict the most appropriate gate settings to use in order to maintain the target water surface elevations upstream. Shown in Figure 9 is an example of two navigation dams operating in series.

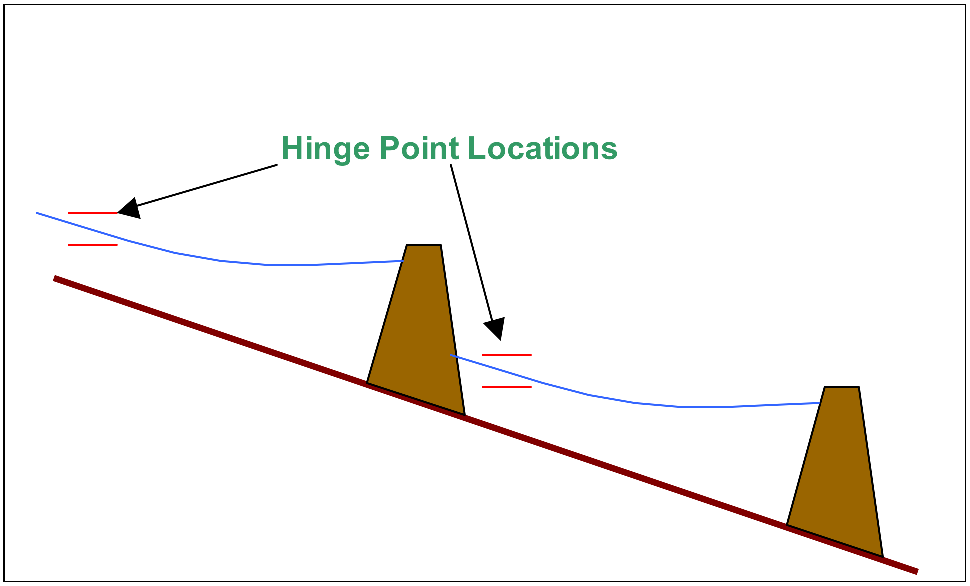


Figure 9. Navigation Dam Operations

Floodway Encroachments

Floodway encroachment analysis has been added to the unsteady flow computations module of HEC-RAS. User's can now perform a Method 1 encroachment analysis (user defined locations) for any unsteady flow plan. However, it is recommended that the user first perform an encroachment analysis in steady flow using any of the five available encroachment methods. Once a reasonable set of encroachments are arrived at from the steady flow analysis, they can be imported into the unsteady flow plan. The unsteady flow analysis is then run, and the encroachments can further be refined to account for the loss of storage and potential increase in peak flow downstream.

Stable Channel Design and Analysis

Three new features have been added to the hydraulic design set of tools in Version 3.1 of HEC-RAS. They are: Uniform Flow Analysis, Stable Channel Design, and Sediment Transport Capacity. These tools are similar to the same ones found in the Coastal and Hydraulics Laboratory's SAM Hydraulic Design Package, only they are built within the framework of HEC-RAS. The Uniform Flow Analysis tool can solve Manning's equation at any cross section in a reach. Equivalent n values are determined from a variety of roughness predictors. The Stable Channel Design tool provides the capability to analyze and design a stable cross section using Copeland's method, regime equations, or tractive force methods. The Sediment Transport Capacity tool allows the user to estimate the total transport capacity of a selected cross section. Sediment reaches are set up from existing RAS cross sections with common hydraulic and sediment characteristics. Six transport functions are available, and cross sections can be broken up into left and right overbank and main channel sub sections. The powerful output features give the user the ability to view transport capacity by grain size, sub section, transport function, or profile.

NEW FEATURES FOR HEC-GEORAS 3.1:

HEC-GeoRAS is an ArcView GIS extension specifically designed to process geospatial data for use with the Hydrologic Engineering Center River Analysis System (HEC-RAS). The menus, buttons, and tools (see Figure 1) allow users with limited GIS experience to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and complementary data sets. Water surface profile and velocity results exported from HEC-RAS can be processed into flood inundation maps and depth and velocity grids.

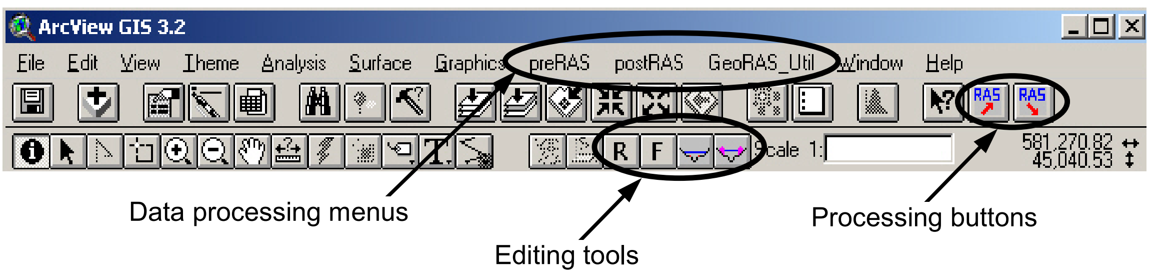


Figure 10. HEC-GeoRAS extension loaded in ArcView GIS.

The methods available through the GeoRAS extension are intended to assist users with hydraulic model development and refinement. Because data is represented visually through GIS displays, GeoRAS offers an additional method to HEC-RAS tables and plots for examining results. Further, because data processing is automated, the iterative procedure of model inspection and refinement can be performed with relative ease. New features available in Version 3.1 of GeoRAS coupled with improvements to HEC-RAS will assist engineers develop and refine river models.

New geometric data supported by HEC-GeoRAS Version 3.1 includes data extraction for levee positions and elevations, ineffective flow locations, and storage area information. Additionally, GeoRAS features cross-section previewing and a bank station locator tool.

XS Plotting

The plotting tool provides user access to preview each cross section before the data is written to the RAS GIS Import File. An interactive point locator tool is provided to identify points along the cross section profile in planar view. This allows for identification of important ground surface features such as bank stations, roads, or levees. The identification of bank stations is illustrated in Figure 11.

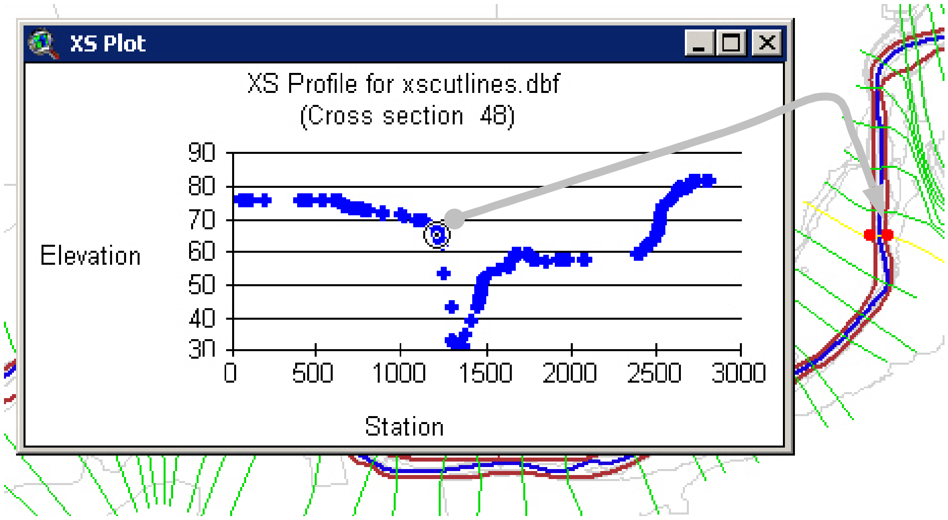


Figure 11. Identification of bank station locations using the XS Plot and Point Identify tools.

Levee Alignments

The position and elevation of levee alignments may be extracted. The levee property is used to identify linear, connected, high ground locations that do not allow water to flow laterally into the floodplain. This feature proves necessary to correctly model linear features adjacent to the floodplain.

Levees that are not incorporated into the terrain model may also be constructed. Once a levee alignment has been created, elevations along the levee line can be added to create a levee profile. This allows for incorporating a proposed levee into the river hydraulics model through the GIS. Levee positions and elevations are then calculated from the levee profile, rather than the terrain model. An example levee profile table with levee alignment is shown in Figure 12.

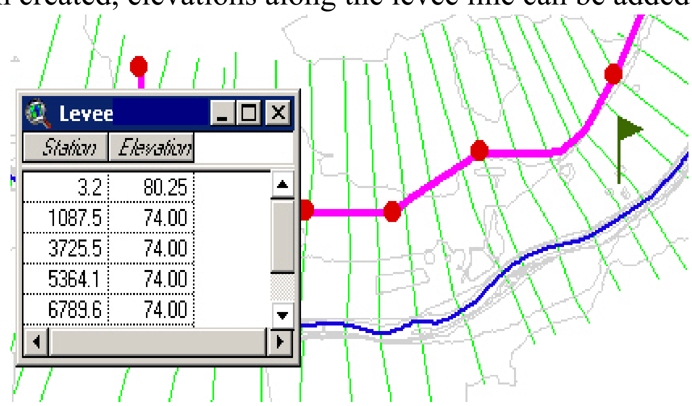


Figure 12. Levee elevations input at user-defined locations.

Ineffective Flow Areas

Ineffective flow areas are used in HEC-RAS to identify portions of cross sections that do not actively convey water. These ineffective areas are identified in the GIS through visual inspection of the terrain model at the approach and exit of bridges and culverts and in slack-water areas. The Ineffective Flow Areas theme is created by digitizing polygons, such as those shown in Figure 13, at non-conveying areas. The intersection of the cut lines and ineffective areas and corresponding trigger elevations are calculated using GeoRAS.

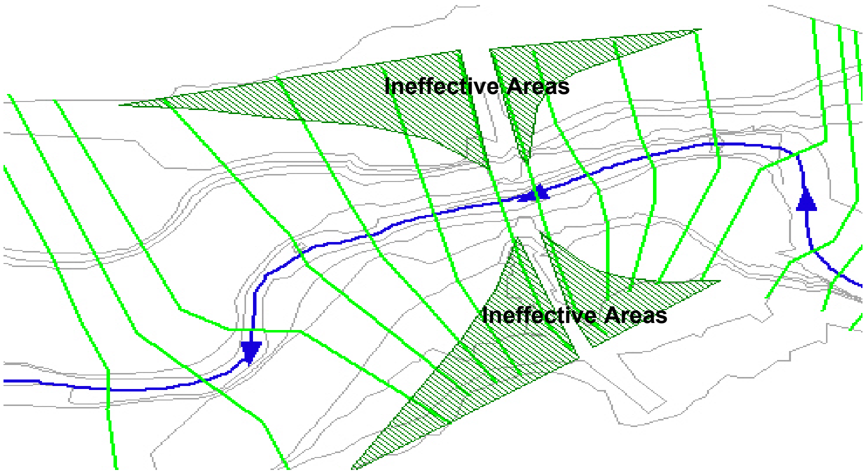


Figure 13. Ineffective flow areas at contraction and expansion cross sections.

Storage Areas

Storage areas are used in unsteady-flow modeling to represent floodplain storage. Storage areas must be connected to the main conveyance channel in HEC-RAS. A storage area is represented by a polygon, as shown in Figure XXX. Elevation-volume information is extracted for the area within the polygon.

Weirs

Lateral weirs are used to connect river reaches to storage areas or other river reaches (see Figure 14). Elevation profile data can be extracted from the terrain model using the cross section plotting tool. Using a spreadsheet, the data extracted for plotting the weir profile can be copied into the Weir/Embankment editor in HEC-RAS.

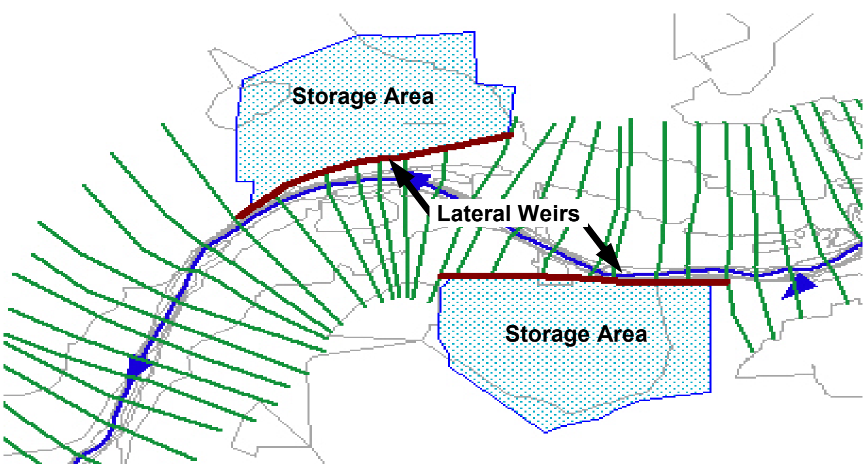
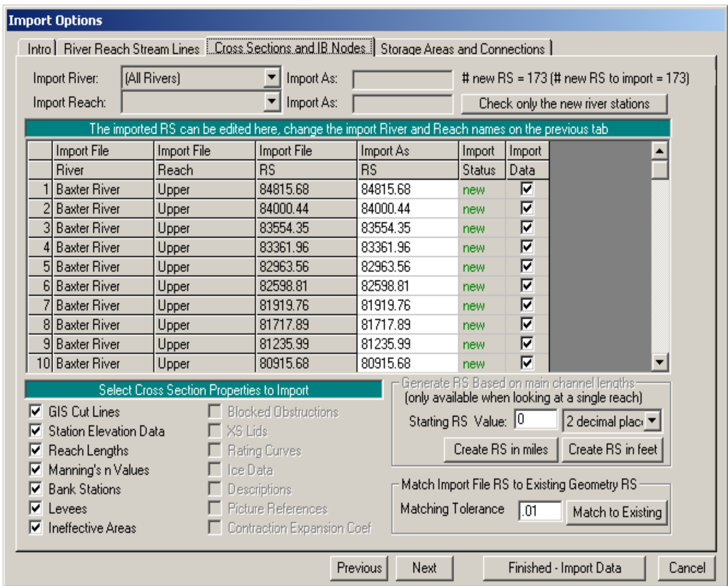


Figure 14. Storage areas are connected to the main channel with lateral weirs in HEC-RAS.

New GIS Importer For HEC-RAS

Geometric data is input to HEC-RAS by importing the RAS GIS Import File. Despite efforts preparing data within the GIS, data must be scrutinized, edited, and completed within HEC-RAS. With Version 3.1 of HEC-RAS the GIS Import Options window and Graphical Cross Section Editor provides excellent tools for importing and modifying data.



The GIS Import Options window allows the user to choose the exact piece of data to import. Users can globally import cross-sectional data, for instance, or import just one property of just one cross section. This provides an enormous amount of flexibility to users that are combining data sets, importing additional data, or modifying existing models with updated data.

Figure 15. GIS data import options window.

In addition to the new import capabilities, HEC-RAS has a new Graphical Cross Section editor that allows the user to graphically modify cross sections. Using the mouse, users can modify geometry, add new features such as levees and ineffective flow areas, or delete features. In addition, tools are provided to quickly change the location of bank stations and the location of roughness coefficients. Different geometry files can also be compared through the editor. The graphical cross section editor provides a valuable tool for verifying and correcting geometry and hydraulic properties import from the GIS.

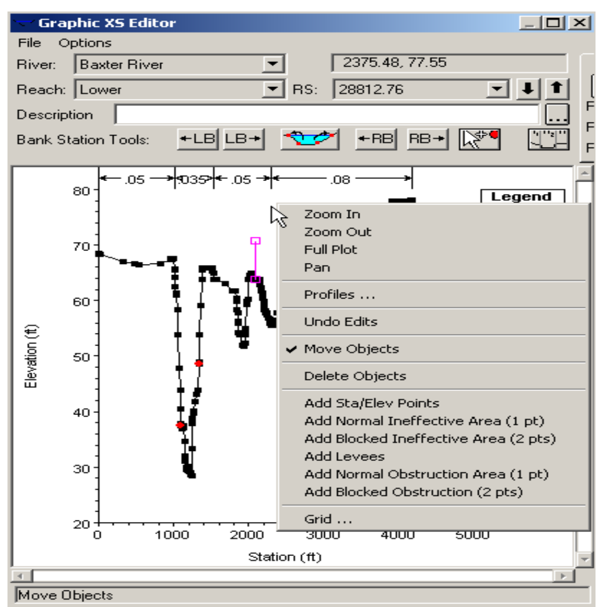


Figure 16. Graphical cross section editor

Future Developments

HEC-GeoRAS 3.1 is the final major release for the ArcView 3.x GIS software. Currently, efforts are focused on developing GeoRAS functionality for ArcGIS 8.x. The ArcGIS version of GeoRAS will have new methods, an improved interface, and additional data import/export capabilities.

HEC is also developing improved floodplain delineation techniques to correctly map areas inundated due to backwater and methods for merging river channel data with floodplain terrain.

REFERENCES

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HEC, 2002. *HEC-RAS (Version 3.1), River Analysis System, User's Manual*, Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, CA.